Measurement of $^3$He Elastic Electromagnetic Form Factor Diffractive Minima Using Polarization Observables

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Parallel Running with $d_2^n$

- $d_2^n$: Measure neutron $g_2$ and $d_2$ at high $Q^2$.
- 53 calendar days 5th-pass production.
- 3 calendar days at 1st-pass for systematics.
  - $^3$He double-polarization asymmetry will run in parallel with these 1st-pass systematics measurements.
  - **No modifications required** to any equipment.
  - Only requirement is to reposition the spectrometers.
Modern $^3$He Form Factors

$^3$He Charge Form Factor

$|F_{ch}(Q^2)|$ vs $Q^2 (\text{fm}^{-2})$

$Q^2 (\text{GeV})$

Representative Fit Barcus 2019
Uncertainty Band Barcus 2019
Representative Fit Amroun et al. 1994
Uncertainty Band Amroun et al. 1994
CST Marcucci et al 2016
$\chi$EFT 500 Marcucci et al 2016
$\chi$EFT 600 Marcucci et al 2016

$^3$He $F_{ch}$ modern sum of Gaussians fits.
Modern $^3\text{He}$ Form Factors

$^3\text{He}$ Magnetic Form Factor

$|F_m(Q^2)|$

$Q^2 (\text{GeV})$

$Q^2 (\text{fm}^{-2})$

$^3\text{He} F_m$, modern sum of Gaussians fits.
Form Factors from Cross Sections

- $^3\text{He}$ cross section at 1 GeV and 3 GeV.

$^3\text{He}$ cross section at 1 GeV.

$^3\text{He}$ cross section at 3 GeV.

- Shallow cross section minima are used to extract sharp form factor minima.
Double-polarization asymmetry at 2.216 GeV. The points show the statistical uncertainty of the mean of each kinematic setting.

- Uncertainties are statistics limited. Systematics are small.
- Offline discussions are ongoing about optimizing these points.
  - Highest kinematic may be removed and split into two points to better measure first zero crossing.
Conclusions

- In collaboration with $d_2^n$ we propose to measure the double-polarization asymmetry of $^3\text{He}$ over a range of $Q^2$.
  - Run in parallel with 1$^{\text{st}}$-pass systematics measurements.
- This will be the first high $Q^2$ measurement of $^3\text{He}$ form factors using polarization observables.
  - Constrain the locations of the diffractive minima.
  - Provide new method to hypothesis test theory predictions.
  - Determine if polarization observables agree with unpolarized Rosenbluth results.
  - Help explain the discrepancies between theoretical predictions and experimental measurements of the $^3\text{He}$ form factors.
- History has shown that polarization measurements can reveal problems with cross section extracted form factors (Jones et al. 2000).
### Backup Slides

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Spectrometer Central Kinematics